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RESEARCH MEMORANDUM

INVESTIGATION OF A RAMP-TYPE INLET DESIGNED FOR IMPROVED ANGLE-OF-ATTACK PERFORMANCE AT MACH NUMBER 2.0

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NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

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SUMMARY

An inlet mounted on the side of a fuselage and utilizing a horizontally oriented 14° ramp located at the top of the inlet was investigated in the Lewis 8- by 6-foot supersonic tunnel at Mach numbers of 1.5, 1.8, and 2.0. The characteristics of this inlet were compared with those of a conventional ramp-type side inlet. While the peak pressure recovery of the conventional inlet decreased with increasing angle of attack, the peak pressure recovery of the horizontal ramp inlet increased at Mach number 2.0 for increasing angle of attack from zero to 3°, then decreased with further increases in angle of attack. At Mach numbers of 1.5 and 1.8, the peak pressure recovery of both inlets decreased as the angle of attack was increased from zero degrees. Up to 4° angle of attack at a Mach number of 2.0, the horizontal ramp inlet maintained thrust-minus-drags at least equal to that obtained at zero angle of attack. At Mach numbers of 1.5 and 1.8, the horizontal ramp inlet thrust-minus-drag decreased with increasing angle of attack at a rate faster than that for the conventional inlet.

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INTRODUCTION

The theoretical pressure recovery of a one-oblique and normal shock system for a two-dimensional ramp-type inlet indicates that, at a given Mach number, there is a range of ramp angles for which near-optimum pressure recovery can be obtained. For example, at a free-stream Mach number of 2.0, a loss of only 2 percent in pressure recovery from the optimum occurs over a range of ramp angles from 12° to 20°. Thus, a horizontally oriented low-angle ramp located at the top of an inlet would theoretically maintain a high pressure recovery over a wide range of angle of attack, since the effective ramp angle increases with angle of attack. This inlet type is applicable for either fuselage-side or wing-root locations. Other techniques employed to improve the angle-of-attack performance of inlets are reported in references 1 to 5.

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The performance of a ramp-type inlet, mounted as a side inlet and utilizing a horizontally oriented 14° ramp located at the top of the inlet for improved angle-of-attack performance at a Mach number of 2.0, was determined over an angle-of-attack range from zero to 9° at free-stream Mach numbers of 1.5, 1.8, and 2.0. The results were compared with a conventional ramp-type side inlet.

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SYMBOLS

The following symbols are used in this report:

A_f maximum model cross-sectional area

A_i inlet capture area

C_D external drag coefficient based on maximum frontal area, $\frac{D}{q_0 A_f}$

D drag

F thrust

M Mach number

$\frac{m_3}{m_0}$ inlet mass-flow ratio, $\frac{\text{inlet mass flow}}{\rho_0 V_0 A_i}$

P total pressure

q dynamic pressure

V velocity

α angle of attack

ρ mass density of air

Subscripts:

s spillage

0 free stream

3 diffuser exit survey station; model station, 66.5

Model reference areas are as follows:

Ramp inlet	Model maximum cross-sectional area, A_f, sq ft	Inlet capture areas, A_1, sq ft
Horizontal	0.3000	0.0228
Vertical	.2765	.0232

APPARATUS AND PROCEDURE

Schematic diagrams of the models used in this investigation are presented in figure 1. Both of the inlet configurations were mounted on the RM-10 body of revolution, which was sting-mounted through a strain-gage balance that measured normal and axial forces. Mass flow through the ducts was varied by remotely controlled plugs that were mounted on the sting.

Photographs of the inlets are presented in figure 2. Figures 1(a) and 2(a) illustrate the inlet that will hereinafter be called the horizontal ramp inlet. This inlet utilized a horizontally oriented 14° wedge located at the top of the inlet. The other inlet tested, called the vertical ramp inlet, is illustrated in figures 1(b) and 2(b). This inlet utilized a 19° ramp that was curved concentric to the circular surface of the fuselage. Both duct cross sections changed from an essentially rectangular cross section at the inlet to a circular cross section about 21 inches downstream of the inlet. The area variations of the two diffusers are presented in figure 3.

Fuselage boundary-layer air was bypassed by displacing the inlets away from the fuselage. Boundary-layer diverter wedges of 16° included angle were used as spacers between the inlets and fuselage, and the diverter height was approximately equal to the boundary-layer thickness at zero angle of attack.

Pressure instrumentation consisted of nineteen total-pressure tubes and six static-pressure orifices located at station 66.5. The average total pressure was determined by an area-weighting method and was used to calculate the mass-flow ratio by assuming the exit area at the mass-flow control plugs to be choked. Base pressures were measured by six symmetrically located static-pressure orifices. The drags presented in this report are the stream-wise components of the measured forces, excluding the base pressure force, and excluding the stream thrust developed by the duct from free stream to exit. Mass-flow ratio was varied at free-stream Mach numbers of 1.5, 1.8, and 2.0, and angles of attack from zero to 9°.

The Reynolds number of the test, based on model length ahead of the cowl lip, was approximately 20×10^{6}.

RESULTS AND DISCUSSION

The pressure recovery and model drag coefficients for both inlets are presented in figure 4 as a function of mass-flow ratio. The vertical ramp inlet (fig. 4(b)) showed decreases in peak pressure recovery with increases in angle of attack. As would be predicted from two-dimensional shock theory, the horizontal ramp inlet exhibited an increase in peak pressure recovery for an increase in angle of attack from zero to 3° at the design Mach number of 2.0. Since the 14° ramp angle was approximately optimum for a Mach number of 1.8 and greater than optimum for a Mach number of 1.5, no increase in pressure recovery was obtained with increasing angle of attack at these Mach numbers. 3571

The vertical ramp inlet showed a decrease in supercritical mass-flow ratio with an increase in angle of attack at all three Mach numbers. For the horizontal ramp inlet, however, at Mach numbers 1.8 and 2.0, the supercritical mass-flow ratios at angles of attack of 3° and 6° were higher than at zero. This is a result, primarily, of the increase in inlet capture area with increasing angle of attack. The decreased mass flows at the higher angles of attack apparently result from the increased spillage behind the detached shock occurring at the higher effective ramp angles. At the free-stream Mach number of 1.5, the leading-edge shock was detached at zero angle of attack for both inlets; consequently, the supercritical mass-flow ratio decreased as angle of attack was increased. No effect on the stability of the inlets due to the detached shock was noted.

For each Mach number, the drag coefficients of the two models were of the same order of magnitude at zero angle of attack and equal mass-flow ratios. Because of a difference in afterbody design, which resulted in a greater projected frontal area at angle of attack for the horizontal ramp inlet, the drag coefficient of the horizontal ramp inlet increased at a greater rate than that of the vertical ramp inlet. This larger projected frontal area at angle of attack need not be a characteristic of horizontal ramp inlets in general. Therefore, in subsequent calculations of thrust-minus-drag, the model drag rise with angle of attack was excluded and only the increase in external drag due to mass-flow spillage was considered.

The pressure recovery and spillage-drag coefficients for the diffuser-exit Mach number at which the inlet might be matched to a typical constant corrected weight-flow turbojet engine are presented in figure 5 as a function of angle of attack. The spillage drag at any angle-of-attack match point is defined as the difference between the drag at the match point and the angle-of-attack drag at a reference mass-flow ratio. The reference mass-flow ratio is taken as the critical mass-flow ratio at zero angle of attack. In cases where extrapolation of the angle-of-attack drag curves to the zero angle-of-attack critical mass-flow ratio was necessary, a straight-line extension to the curve was used. The pressure recoveries at the matching condition correspond closely to the peak pressure recoveries of the inlets, and behave similarly with variations in angle of attack as already discussed from figure 4. The difference in spillage drags between the two inlets at Mach numbers of 1.5 and 1.8 is not great and decreases slightly with increasing angle of attack. At a Mach number of 2.0, the difference between the spillage drags of the two inlets increases with angle of attack, with the horizontal ramp inlet having the lower value.

A thrust-minus-drag comparison of the two inlets is presented in figure 6. The comparison is made on the basis of an available thrust ratio defined as the ratio of the thrust-minus-spillage-drag at the
3571 match point at each angle of attack to the thrust-minus-spillage-drag for the match point at zero angle of attack. At the design Mach number of 2.0, thrust-minus-drag of the horizontal ramp inlet was greater than that for the vertical ramp inlet. An increase in the available thrust ratio at angles of attack from zero to 3° was obtained, and an advantage of thrust-minus-drag over the vertical ramp inlet was maintained over the entire angle-of-attack range. This advantage for the horizontal ramp inlet arises from the initial gain in pressure recovery and lower spillage drag. At the off-design Mach numbers 1.8 and 1.5, the horizontal ramp inlet had lower values of available thrust-minus-drag than the vertical ramp inlet because the ramp angle was greater than optimum.

SUMMARY OF RESULTS

The characteristics of a ramp-type inlet utilizing a horizontally oriented 14° compression surface located at the top of the inlet were determined and compared with those of a conventional ramp-type side inlet. Data were obtained at free-stream Mach numbers of 1.5, 1.8, and 2.0, and through a range of angles of attack from zero to 9°. The results are as follows:

1. As predicted from two-dimensional shock theory, the peak pressure recovery of the horizontal ramp inlet increased for an increase in angle of attack from zero to 3° at a Mach number of 2.0, then decreased with further increases in angle of attack. At Mach numbers of 1.5 and 1.8, the pressure recovery decreased with angle of attack.

2. At the design Mach number of 2.0, the thrust-minus-spillage-drag of the horizontal ramp inlet increased as the angle of attack increased from zero to 3° and maintained an advantage of thrust-minus-spillage-drag over the vertical ramp inlet over the whole angle-of-attack range. At Mach numbers of 1.5 and 1.8, the vertical ramp inlet had the superior angle-of-attack performance.

Lewis Flight Propulsion Laboratory
National Advisory Committee for Aeronautics
Cleveland, Ohio, December 14, 1954

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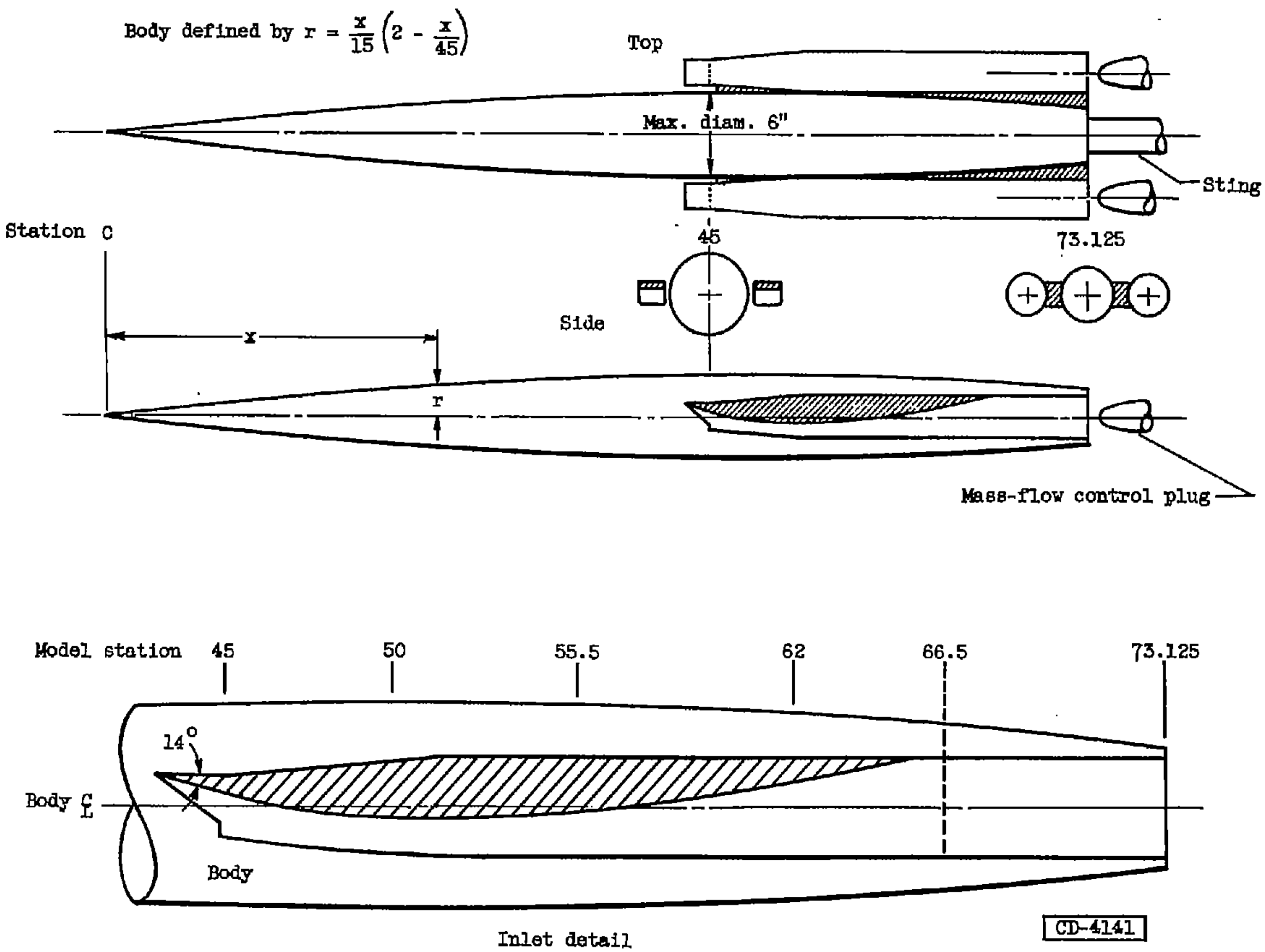

Inlet detail

(a) Horizontal ramp inlet.

Figure 1. - Schematic drawing of model.

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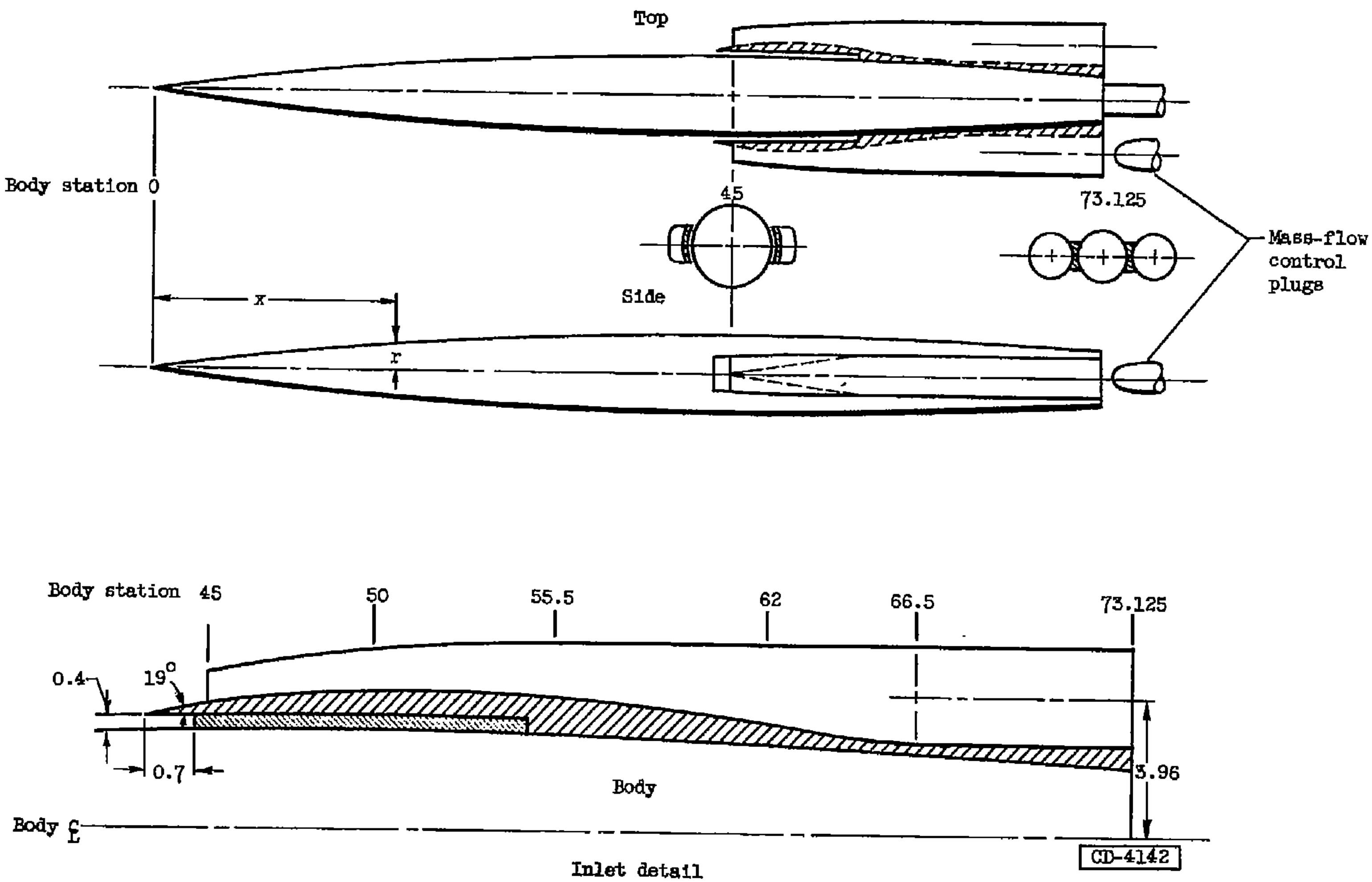

(b) Vertical ramp inlet.

Figure 1. - Concluded. Schematic drawing of model.

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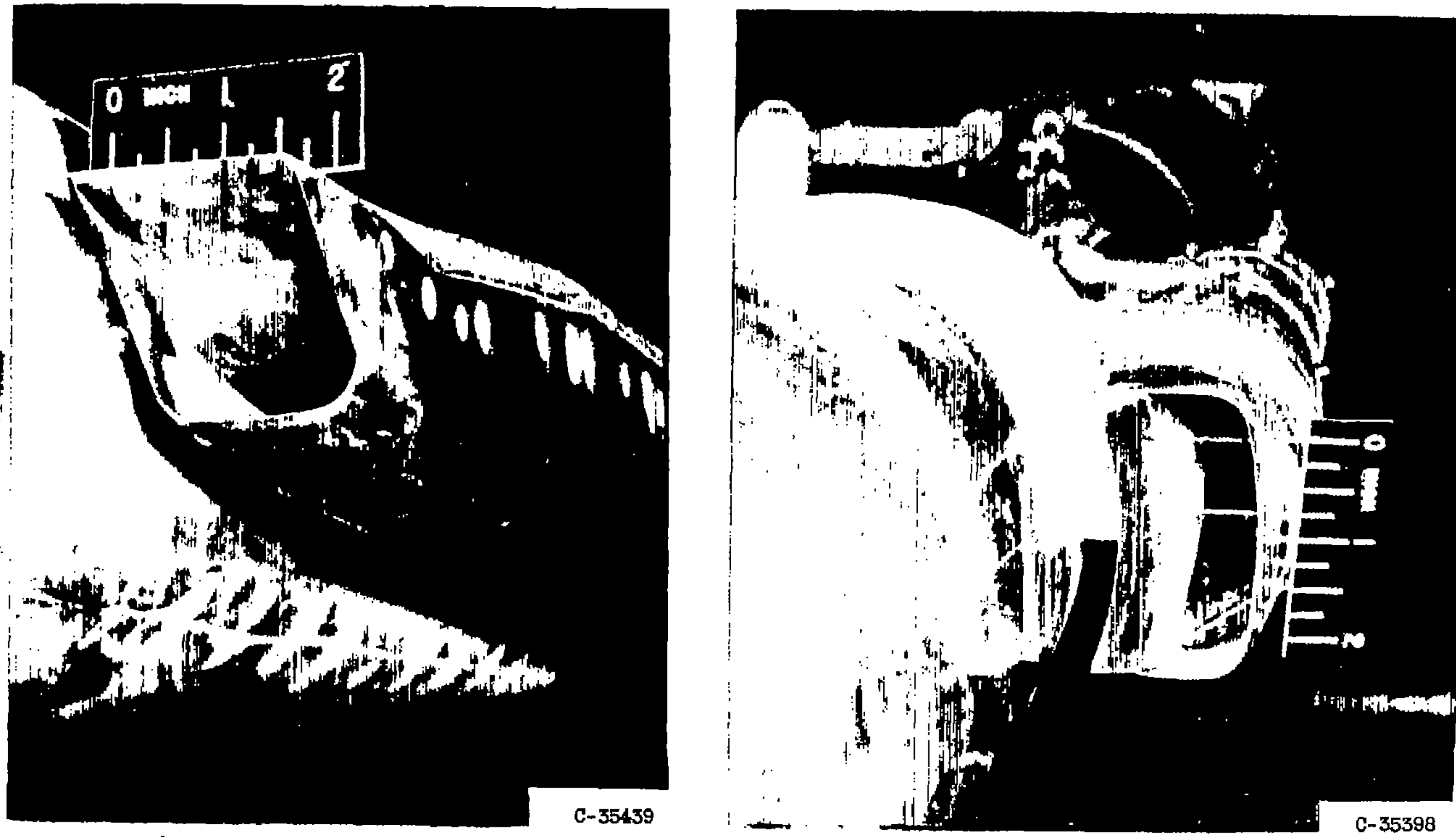

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(a) Horizontal ramp inlet.

(b) Vertical ramp inlet.

Figure 2. - Photographs of inlets.

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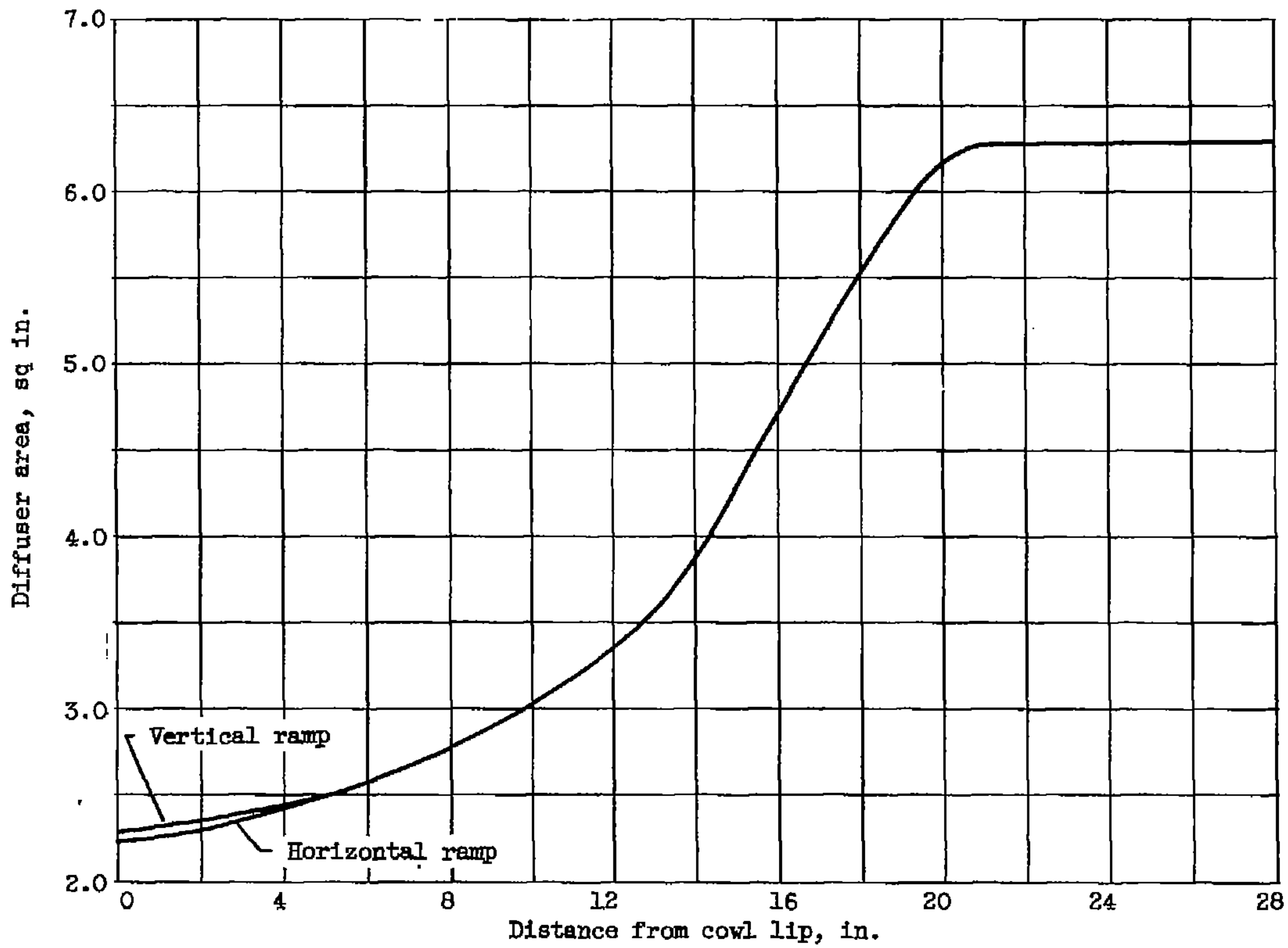

Figure 3. - Diffuser area variation.

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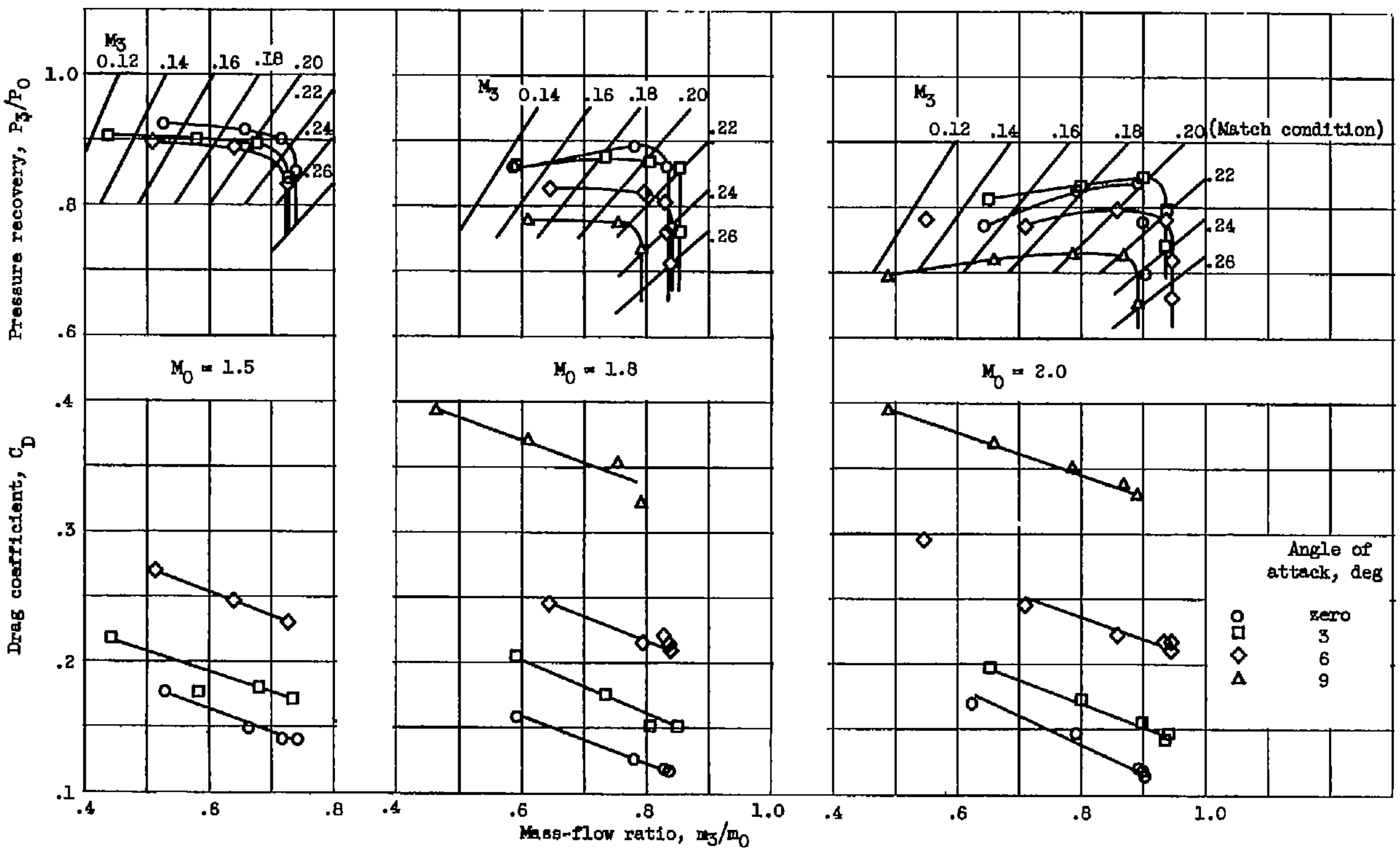
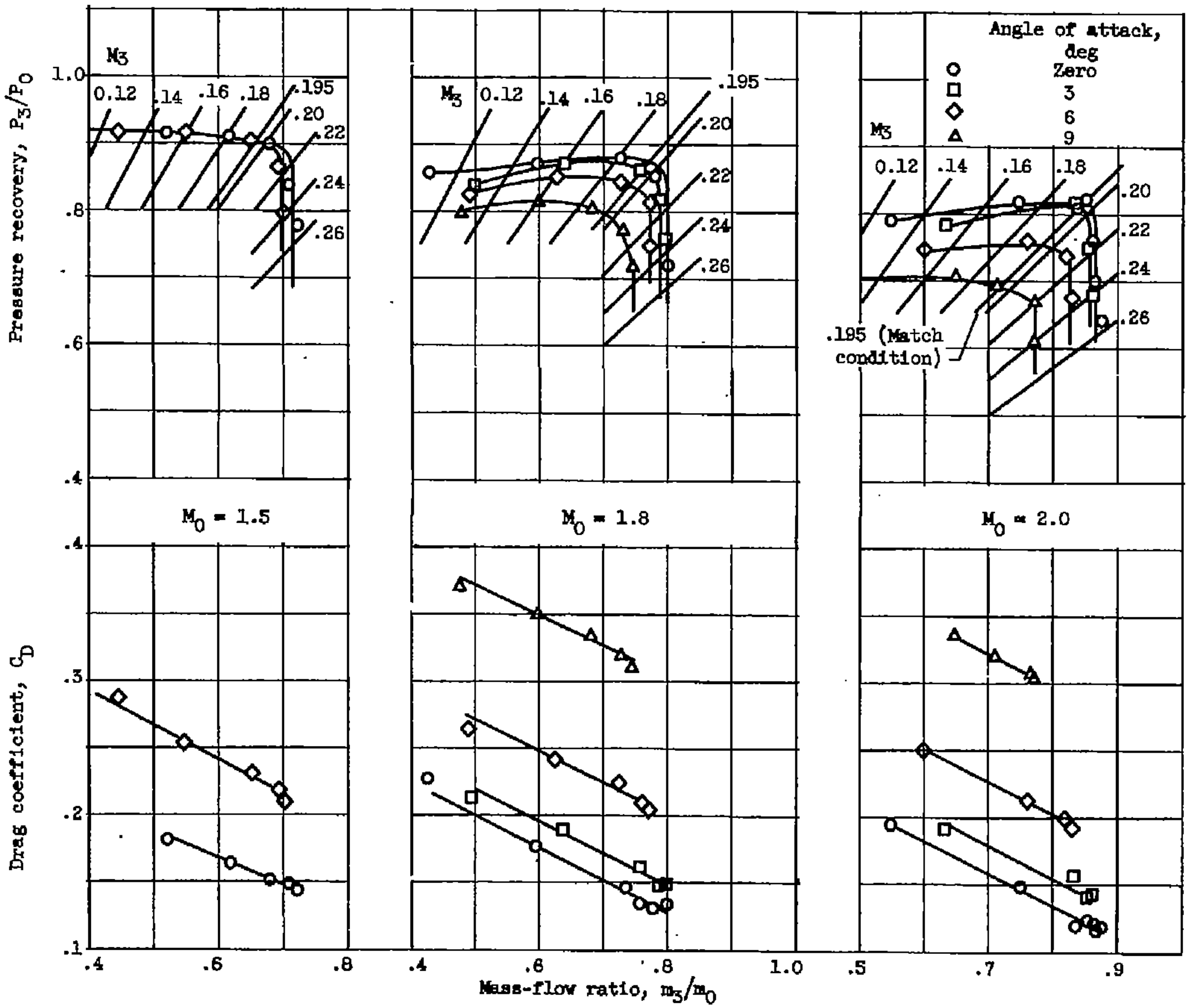


(a) Horizontal ramp inlet.

Figure 4. - Pressure recovery and drag characteristics.



(b) Vertical ramp inlet.

Figure 4. - Concluded. Pressure recovery and drag characteristics.

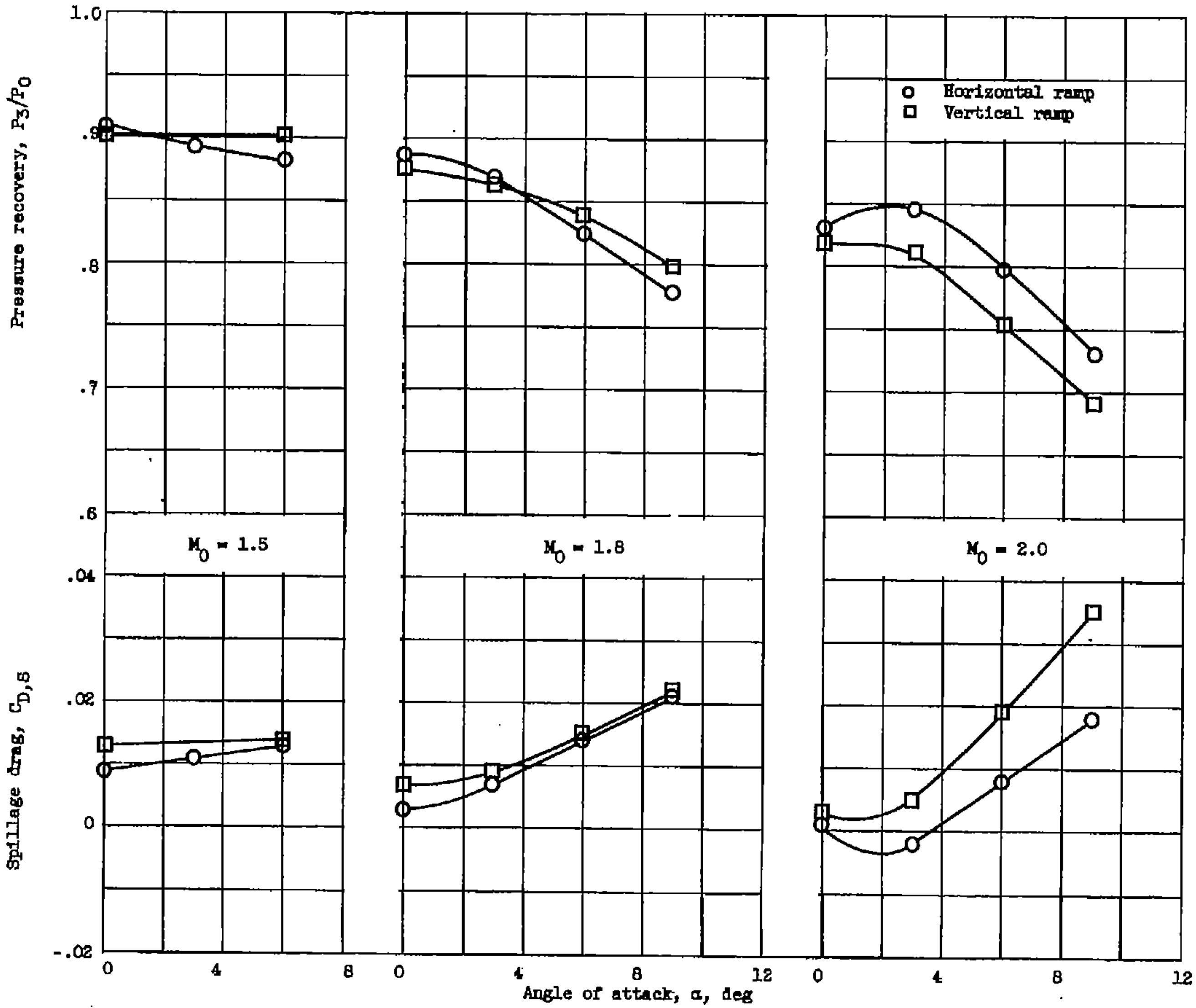


Figure 5. - Pressure recovery and spillage drag at match diffuser-exit Mach number.

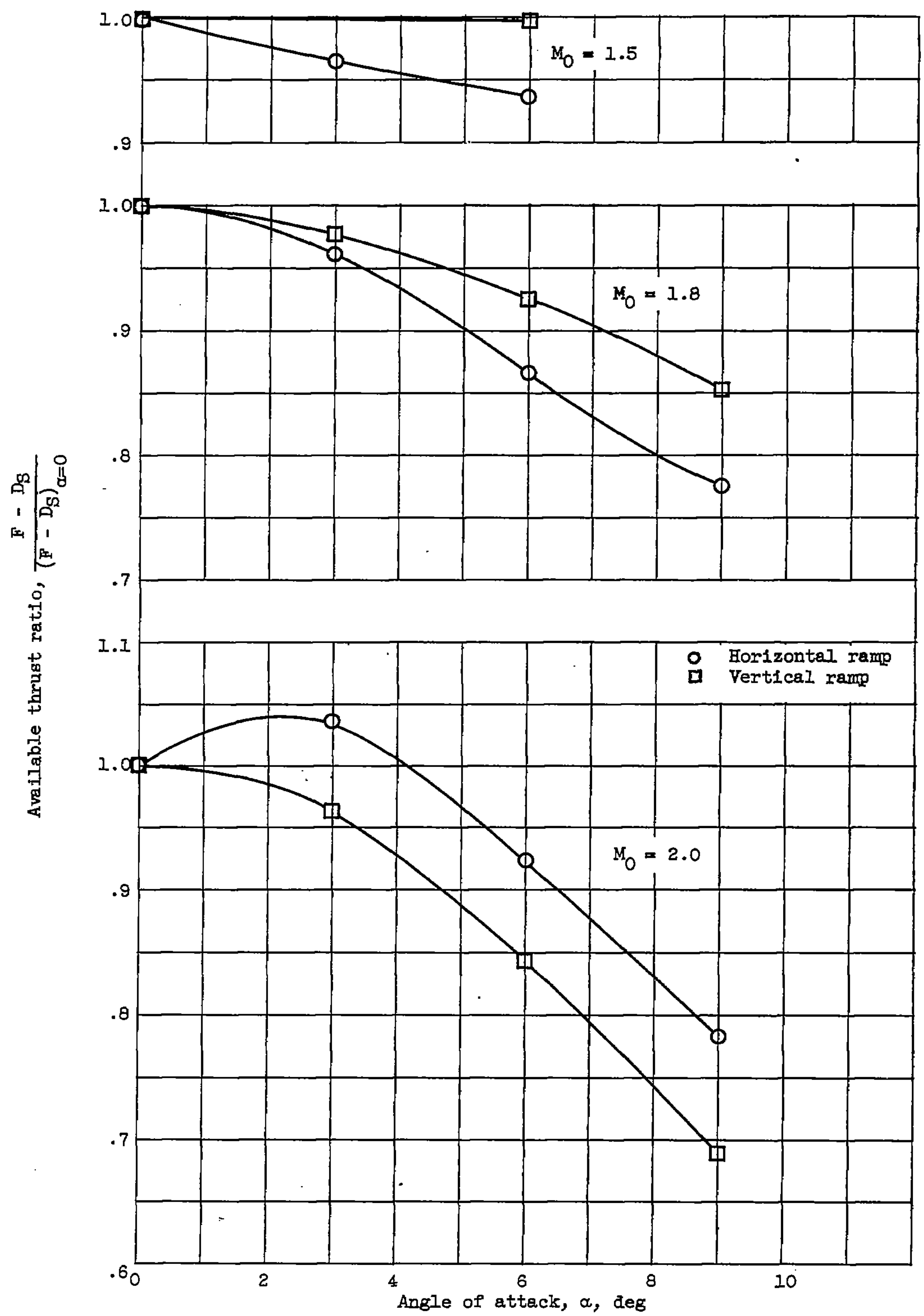


Figure 6. - Inlet performance comparison at match diffuser-exit Mach number.